Comments on "Cloud-resolving model simulations of multiply-banded frontal clouds" by Pizzamei et al. (2005)

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1. Introduction

Pizzamei et al. (2005; hereafter P05) perform an idealized modeling study to examine possible mechanisms for observed cases of stacked slantwise convective circulations, one of which is presented by Browning et al. (2001; hereafter B01). I argue in these comments that the results from P05's model simulations do not resemble B01's observed case by virtue of the initial conditions of the front and related formulations used in their idealized modeling experiments. By extension, I also argue that their model simulation does not represent other cases of banded frontal circulations.

2. Frontal forcing and structure

A critical omission in P05's model simulations is large-scale deformation to produce frontogenesis. Had frontogenesis been acting in the model simulation, the secondary circulation associated with the front might have been sufficient to initiate convection. The absence of large-scale deformation to maintain frontogenesis means there would be no secondary circulation associated with the low-level frontal zone to assist in continuously lifting air parcels to their level of free convection (whether through slantwise or upright ascent). Instead, the introduction of the warm bubble by P05 is required to initiate convection, and the subsequent convective storm is needed to maintain the ascent along the front to form the multiple bands in the model simulation. Although such a warm bubble is needed in idealized simulations of deep, moist convection employing horizontally homogeneous initial conditions, the present simulation could have been constructed in such a manner that such artificialities were not needed. Indeed, several other idealized modeling experiments of multiple bands along fronts have been performed in the past—none requiring such a warm bubble. For example, Knight and Hobbs (1988) use the Eady (1949) model to produce the initial conditions to drive frontogenesis. In another example, Xu (1992) uses a geostrophic forcing function to maintain frontogenesis. Were large-scale deformation present in B05, as in Knight and Hobbs (1988) and Xu (1992), the secondary circulation would act as a continuous lifting mechanism, obviating the need for the warm bubble. The absence of large-scale deformation to produce frontogenesis is a crucial omission that alters the very nature of the idealized simulations, making them a poor representation of observed fronts.

Another characteristic of P05's model simulation that is unlike B01's front is the initial specification of the frontal zone. Whereas the observed frontal zone is deep and sloping, extending up to 5 km at the left edge of the figure (Fig. 4a in B01), the modeled front is shallow and nearly horizontal, not extending above 2.5 km (Fig. 1a in P05). Their model simulation disregards this potentially important aspect of the observed case: the presence of an upper-tropospheric potential vorticity anomaly that descends as low as 3 km above the surface (Fig. 4b in B01). The potential for this feature to aid in ascent over the front is unaccounted for in the idealized model simulation (Fig. 1 in P05). The absence of the upper-level potential vorticity anomaly results in a fundamentally different structure and evolution to the modeled case than observed. For example, infrared satellite imagery and operational numerical model output (Figs. 3b and 4e in B01, respectively) show relatively deep clouds associated with the cold front, extending to at least 10 km in the model. By comparison, saturated areas in the idealized simulations of P05 rarely reach even 4 km above the surface (e.g., Figs. 5c, 6c, 7c, and 8c in P05). The upper-level potential vorticity anomaly is likely contributing to making the frontal circulation deeper than it would be otherwise. The depth of the cloud may be one factor in the model's inability to produce the stacked slantwise circulations, discussed in the next section.

3. Comparison to observed stacked slantwise convective circulations

By failing to produce a frontal structure structurally and dynamically similar to that observed, the model simulations by P05 fail to produce the stacked slantwise convective circulations resembling those observed by B01. Whereas the observed circulations have gentle slopes and are vertically stacked upon each other above the surface (Figs. 6a,b and 7 in B01), the modeled circulations appear to be steeply sloped, separated in the horizontal, and surface based (Figs. 6a and 7a in P05). Any appearance of gently sloping stacked circulations occurred early in the model simulation (around 6 hours) and appeared to be similar to gravity waves radiating away in both directions (P05, their Fig. 5a).

Whether the bands are associated with surface-based convection or elevated convection is a significant difference, which may explain their cause. For example, the second slantwise circulation in B01 has "no clear evidence of well organized low-level confluence that might have been associated with any line convection" (B01, p. 2523), suggesting that an elevated instability released by the frontogenesis may be responsible. In contrast, the second convective episode (CE2) in P05 is associated with low-level convergence due, in part, to the evaporatively cooled downdraft air (P05, their pp. 2627–2628). This discrepancy suggests that different mechanisms are likely responsible for the bands in both the observations in B01 and the model in P05.

4. Conclusions

Browning et al. (2001) presents a fascinating case of stacked slantwise convective circulations from radar observations; other such cases of multiple banding along frontal zones have also been documented. Pizzamei et al. (2005) attempt to simulate these stacked circulations using a high-resolution numerical model. I argue that P05 fail to adequately reproduce the observed structure owing to the formulation of their model simulation, and, as a result, the structures modeled by P05 do not resemble the observed slantwise circulations observed by B01 or other observed multiply banded frontal zones.

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REFERENCES

Browning, K. A., D. Chapman, and R. S. Dixon, 2001: Stacked slantwise convective circulations. *Q. J. R. Meteorol. Soc.,* **127,** 2513–2536.

Eady, E. T., 1949: Long waves and cyclone waves. *Tellus,* **1**(3), 33–52.

Knight, D. J., and P. V. Hobbs, 1988: The mesoscale and microscale structure and organization of clouds and precipitation in midlatitude cyclones. Part XV: A numerical modeling study of frontogenesis and cold-frontal rainbands. *J. Atmos. Sci.,* **45,** 915–930.

Pizzamei, M., S. L. Gray, and K. A. Browning, 2005: Cloud-resolving model simulations of multiply-banded frontal clouds. *Q. J. R. Meteorol. Soc.,* **131,** 2617–2637.

Xu, Q., 1992: Formation and evolution of frontal rainbands and geostrophic potential vorticity anomalies. *J. Atmos. Sci.,* **49,** 629–648.